**Building a Decision Tree for Watermark Identification in Rembrandt's Etchings—
The WIRE Project
Project Co-Directors: Andrew C. Weislogel and C. Richard Johnson, Jr.**

Led by Andrew C. Weislogel, C. Richard Johnson, Jr., and Brittany R. Rubin, the Watermarks in Rembrandt's Etchings (WIRE) Project is designed to broaden access to crucial paper information elucidating the printmaking practice and chronology of Dutch artist Rembrandt Harmensz. van Rijn (1606–1669) by blending digital, computational, and art historical methodologies. Based on the decision tree model, it allows nonspecialists to rapidly and confidently identify Rembrandt watermarks found on Rembrandt's etchings for dating purposes and for reconstructing possible print editions. Over the term of this grant, the WIRE project has constructed decision tree branches for each of the dozens of discrete watermark types found on Rembrandt's papers, resulting in a decision tree coded into purpose-developed software. The decision tree provides proof of concept for application to the etchings of Rembrandt and those other printmakers who used similar laid papers, as well as more broadly to other research questions requiring categorization and differentiation based on observable features. Finally, the grant activities and relationships made with partner institutions during the grant term offered insights regarding the usefulness of a broader database for Rembrandt watermarks in American collections and beyond.

Project Activities

Convening semester-long undergraduate research seminars to advance the project [Months 1–20]: These for-credit research seminars, blending aspects of the engineering research group and the art history seminar approach steeped students in the vital background scholarship on Rembrandt's prints and watermarks, and trained them in the process of creating decision trees, type by type.

Crafting the Interrogatory Decision Tree [Months 1–30]: The project's chief goal was the development of a full decision tree for the identification of all workable types of watermarks in Rembrandt's papers and their known subvariants (Appendix A). The process involves visually isolating unique differentiating features for each watermark variant in a given type, and then crafting a series of yes or no questions to construct a branching graph that guides the researcher to the correct match for a sought watermark. The team continually critiqued and refined watermark features, questions, and branch structure to outline the best and clearest path to the correct answer in each case. This necessitated the development of a standardized vetting process (Appendix B). One by-product of the decision tree is that previously unseen watermark variations clearly stand out and can be identified for further cataloguing and study, because they do not fit the structure of observed features. The project has identified 25 such new variations.

Decision Tree Software development [Months 1–30]: Concurrently with the development of individual decision tree branches, WIRE project students and staff constructed and refined the online watermark identification tool beyond its pre-existing form, which had been first presented on a touchscreen kiosk in Cornell's Herbert F. Johnson Museum exhibition *Lines of Inquiry: Learning from Rembrandt's Etchings* as the grant term began, to enable visitors to explore and grasp the WIRE concept. The hiring of NEH-funded programmer Craig Riecke helped the WIRE website transition onto a stable and expandable platform with the help of WIRE students who also provided design skills and feedback to make the web

interface more user-friendly and attractive. Other modifications to visual appearance, format, and sequence of the decision tree software pages took place throughout the grant period, resulting from both internal reconsideration and external feedback from partners. The result constitutes a significant expansion and improvement of the tool in scope and effectiveness.

Student research and presentations initiate and deepen partnerships with institutions willing to share Rembrandt watermarks data [Months 1–30]: Due to promotion of the WIRE project through conference presentations, papers, and workshops, we experienced increased interest in the project and initiated relationships with new institutional partners holding previously unidentified watermarks. In the first month of the grant, former and current WIRE project students presented a talk at a symposium in conjunction with the Johnson Museum's exhibition *Lines of Inquiry: Learning from Rembrandt's Etchings*; as a result, the Mead Museum of Art at Amherst College and Smith College Museum of Art became project partners. In addition, following a workshop at a study day for scholars given by Dr. Weislogel at the Allen Memorial Art Museum, Oberlin College, on April 6, 2018, the paper conservator and curator at the nearby Cleveland Museum of Art became a crucial partner. In April 2019, Dr. Weislogel and Ms. Rubin took three WIRE project students to the Morgan Library & Museum in New York City, where they presented case studies of specific watermarks in the Morgan's collection to an audience of the Morgan's paper conservation staff.

Summer student work group at Cornell, led by Drs. Weislogel and Johnson, and Ms. Rubin [Month 9]: This program drew interest from a wide range of participants, from advanced undergraduates to museum professionals and seasoned paper conservators, necessitating its recasting as a fully developed workshop with lectures and invited expert Rembrandt scholar Dr. Stephanie Dickey. Existing decision tree branches were tested and a new, complex branch constructed and tested for the Arms of Amsterdam watermark.

Drs. Weislogel, Johnson prepare and submit publication on project findings to a peer-reviewed journal. [Months 16–30]. In addition to numerous catalogue essays, conference papers and articles on the project for relevant professional organizations , the first peer-reviewed journal article describing the decision tree process for the WIRE project as applied to the Rembrandt etchings held by the Frick Collection in New York appeared in June of 2020. This will be followed by a second article co-authored by Johnson and Weislogel currently in production, devoted to describing the online interface and cataloguing new watermark tools and discoveries made during the term of the grant.

Accomplishments

The most significant accomplishment in the course of achieving the project's stated goals was the dissemination of the project's ideas to colleagues and the development of a consortium of partner institutions. This was accomplished in following ways:

Experimentation on and Refinement of the Interrogatory Decision Tree Process: This procedure, established prior to the grant, developed significantly in the series of semester-long research seminars which provided the climate for assessment and improvement through close looking, debate, and dedicated vetting tools. The consultation of different collections, and the feedback obtained from presenting on the project to knowledgeable members of the field, also contributed to improvement of the decision tree process, and will continue to in the future.

Improvements to the WIRE decision tree online identification tool: As of the completion of the grant period, the online decision tree tool features fully 44 of the 48 possible watermark types in Erik Hinterding's 2006 taxonomy, for a total of 497 of the 562 complete watermark images it publishes. To address concerns about users' lack of familiarity with the very specific vocabulary used to describe watermark features, Margaret Canfield, Cornell Class of 2020, developed a set of labeled glossary images for each watermark branch, which pop up when the user scrolls over uncommon terms in decision branch questions. (See Appendix C). To address feedback about the legibility and capability for enlargement of both the queried image and the comparison images as users navigated each question, WIRE project programmer Craig Riecke activated a feature to allow greater user control of enlarging images. We also reorganized the visual ingredients of each question page to ensure that all key visual and textual information appears within the user's field of view with minimal scrolling. Most recently, Isabella Dobson, Cornell Class of 2021, replaced the watermark radiograph images on the "Identify Your Watermark" page with schematic tracings to enable easier identification of types to enable the user to select the correct decision tree branch; this change was also spurred by user feedback. As of this report, both a written instruction manual for the creation of decision tree branches and their coding into the WIRE decision tree software have been completed, and the programmer has made the code freely accessible.

Creation of institutional watermark reports: While the decision tree development proceeded, project leaders maintained efforts to connect with other collecting institutions by drafting reports identifying watermarks on their as-yet unexamined Rembrandt prints. This developing facet of the project holds important implications for the broader adoption of the WIRE watermark interface, and the construction of a watermark database.

Expansion of the proposed student work group into a fully developed workshop: Proposed as an undergraduate work group, the program was expanded to include curatorial professionals and paper conservators, with an alternating lecture/task structure and a guest speaker.

Participation in *Laboratory Rembrandt* exhibition, Fall 2019: In March 2019, the Rembrandt House Museum in Amsterdam invited the WIRE project to participate in the exhibition *Laboratory Rembrandt*: *Rembrandt's Technique Unraveled* (September 21, 2019–February 20, 2020) via an in-gallery didactic designed by Weislogel and Rubin, that simulated the WIRE software for Rembrandt House Museum visitors (Appendix D). This introduced the WIRE project to a new and important audience of Rembrandt specialists and enthusiasts. This spotlight in a significant international exhibition established a research collaboration of broader scope with an international partner.

Plans for completion of project goals. The WIRE watermark identification tool is complete in beta form, and will be shared for further testing and evaluation from peer institutions, as outlined in the original proposal. Specific ongoing website upgrades include: 1) the continued upgrading of placeholder watermark images; 2) the continued input of information on final match pages regarding paper batch dating and other impressions appearing on the same paper; and 3) expansion and editing of the resources section of the website. All of these changes fall within the capability of the ongoing undergraduate WIRE project intern. We will also extend the position of our existing WIRE project programmer Craig Riecke in a website maintenance role for the coming year.

Audiences

Audiences for the WIRE project during the term of the grant ran the gamut from the most celebrated Rembrandt print specialists to museum visitors in both the US and Europe. Those impacted constitute an impressive geographic range, including students and museum curators from nine states and five foreign countries. For a breakdown of the different audiences reached, see Appendix E.

Like the audiences, impacts of the projects were seen in both intentional actions and in serendipitous learning opportunities arising from contact with others around the project concepts and materials. The common thread of this impact remains a realization and an appreciation of the importance that artists' materials hold for an understanding of their practice. Curatorial and paper conservation specialists were energized to delve more deeply into their collections and reconsider previous conclusions about dating and print production. Private collectors learned about how and when Rembrandt's prints were produced. Undergraduate students realized the key role of close looking and openness to research strategies to make new statements even about one of the most studied western artists in history.

Graduate and professional students and academics in both the sciences and the humanities acknowledged the value of studying paper characteristics for broad application in curatorial and academic research on works on paper. Community members of all ages attending public programs and museum exhibitions such as *Lines of Inquiry: Learning from Rembrandt's Etchings* in its two venues (Cornell University and Oberlin College, Fall/Spring 2017–18, totaling 40,742 visitors) and *Laboratory Rembrandt*: *Rembrandt's Technique Unraveled* (September 21, 2019–February 20, 2020, totaling 103,417 visitors) interacted with gallery versions of the decision tree tool both in the early stage of the grant and near its endpoint.

Evaluation

The evaluation of the WIRE project progress took a two-pronged form: 1) students completed peer-to-peer evaluations of developing decision tree branches by means of standardized vetting worksheets to ensure that branch diagrams were ready to be coded into the decision tree software; and 2) software evaluations from curators and conservators at our own and participating peer institutions. Further evaluations were obtained from the participants of the WIRE Summer 2018 workshop that speak not only to their experience of the week's educational offerings but also to their assessment of the project's value to their career development and to the field. Finally, feedback on project progress and discoveries was also provided along the way by WIRE project advisory group members and the staff of museums where students presented during the grant term.

Peer to peer student evaluations of decision tree branches (Appendix B) were immensely helpful in quantifying to what extent the annotated images and questions presented facilitated clear paths to watermark identification. Evaluations from peer institutions uniformly combated assumptions about the workability of the tool based on our closeness to the project, and resulted in corrections and innovations.

Although student participation is at the heart of the project, an evaluative eye reveals the importance of robust support at the outset for professional programming assistance to maintain continuity as students transitioned on and off the project. Thus, the decision to repurpose funds from a proposed database

consultant to a professional programmer made all the difference in developing a strong product and supporting students (and project staff) of varying comfort levels with the website's capabilities and the practice of coding.

Response to the project in both the innovations it offers to the field, and in its service component of helping institutions and various types of learners become more familiar with Rembrandt's prints, has been very positive. Genevra Higginson, a young curatorial professional who attended the WIRE summer workshop reflected about the WIRE project: "It's making me think about what additional data would be helpful to catalogue, what could be beneficial for the public to see on a website, and how to better track those elements in curatorial departments... Getting to spend time, both during workshop exercises and outside of the museum, with students and professionals who have devoted themselves to Rembrandt and works on paper was a complete thrill." The project was also featured in a February 2019 article in the *Art Newspaper*, detailing project goals and progress. Likewise, in February 2019, the catalogue for the *Lines of Inquiry* exhibition was awarded College Art Association's Alfred H. Barr, Jr. Book Award for Smaller Museums, Libraries, Collections and Exhibitions. About its detailing of the WIRE project, the prize jury wrote: "This project at Cornell University…will make a significant contribution to print scholarship and Rembrandt studies, among other fields."

Long-term Impact

The success and visibility of WIRE project, and the many collaborative relationships it has established, have opened several related avenues for continuing and extending its goals. The consortium of partner institutions established during the grant period offers a model of collaboration in the digital humanities and constitutes a roster of knowledgeable colleagues both in the US and Europe for testing of the WIRE interface. Further, Dr. Weislogel and Ms. Rubin will present a talk on the project at the annual conference of the International Association of Paper Historians (now postponed to July 2021 due to the COVID-19 pandemic) that will reach a previously untapped, more bibliographically oriented scholarly audience. WIRE project methodology also has much to offer in extending the decision tree to include Rembrandt's contemporaries and pupils who made prints, such as Ferdinand Bol (1616–1680). Documenting Bol's watermarks and seeking matches between Bol's printing papers and Rembrandt's is underway, initiated by the publications of scholars such as WIRE partner Leonore van Sloten of the Rembrandt House Museum, Amsterdam. A parallel initiative to develop a noninvasive, nonradiographic imaging tool for watermarks and chain lines is underway at the Yale Center for the Preservation of Cultural Heritage under the leadership of its director and WIRE project collaborator Paul Messier; if this tool is successful, many smaller institutions and private collections of Rembrandt prints could be imaged in sufficient quality for watermark identification, cataloguing, and database input. Finally, the Johnson Museum retains a long partnership with the Cornell High Energy Synchrotron Source (CHESS) here in Ithaca; we are exploring with them the possibility of expanding WIRE's interest in paper characteristics to seek new ways of imaging paper to find alternate methods of dating.

The support of NEH lent the WIRE project a legitimacy in the field to enable the introduction of a new resource for Rembrandt studies. Establishing the decision tree as a workable entity will, we believe, establish a new outlook on classification tasks of this type. Even in the short-term absence of significant funding for continuation, WIRE project staff will continue to field questions arising from users of the WIRE decision tree tool, to visit and identify watermarks for institutions and individuals, and consult with colleagues engaged in related projects with a need for visual differentiation and classification

among an extensive library of images. WIRE project staff will continue to field questions arising from users of the WIRE decision tree tool, to visit and identify watermarks for institutions and individuals, and consult with colleagues engaged in related projects with a need for visual differentiation and classification among an extensive library of images.

Products

The chief product of this award is a functional online tool for the identification of the watermarks found on Rembrandt's papers, which will be distributed as indicated to institutional partners for further testing. That website is available [here](#) (for screenshots of a sample branch, see appendix F). The code for the website is located in a GitHub repository [here](#). A complete, PDF instruction manual for the creation and coding of decision tree branches is found under Appendix G of this document.

A peer-reviewed journal article on the decision tree process for this application has already appeared and is accessible by clicking the hyperlink in the "Projects" section. A second article is in preparation as of this writing.

Appendices

- Appendix A: Full List of Rembrandt Watermark Types in Decision Tree
- Appendix B: Sample Decision Branch Vetting Sheet
- Appendix C: Screen shots of WIRE Glossary Images
- Appendix D: Installation shots from WIRE Project decision tree visitor interactive in *Laboratory Rembrandt* exhibition, Rembrandt House Museum, Amsterdam, Fall 2019
- Appendix E: Speaking Engagements and Audiences for WIRE project staff and students
- Appendix F: Screen shots of WIRE Decision Tree website, from welcome page to completion of a representative branch
- Appendix G: Isabella Dobson, "WIRE Decision Tree Instruction Manual," Spring 2020

Appendix A: Full list of Rembrandt Watermark Types in the WIRE Decision Tree

The approximate number of individual watermarks coded for each branch is noted in parentheses:

1. 4HS (1)
2. Anchor (1)
3. Arms of Amsterdam (30)
4. Arms of Baden-Hochberg (3)
5. Arms of Bern (7)
6. Arms of Bristol (2)
7. Arms of Burgundy and Austria (2)
8. Arms of Colbert (2)
9. Arms of Ravensburg (5)
10. Arms of England (1)
11. Arms of France (1)
12. Arms of Kyburg (1)
13. Arms of London (1)
14. Arms of Ravensburg (4)
15. Arms of Württemberg (6)
16. Basel Crosier (11)
17. Basilisk (9)
18. Countermark Letters: A (5), D (2), F (7), G (4), H (3), I (16), J (1), L (9), M (3), N (8), O (1), P (21), R (12), V (3), W (3), Y (0)
19. Cross (2)
20. Cross of Lorraine (4)
21. Dovecote (1)
22. Eagle (17)
23. Fleur de Lys (6)
24. Foolscap with Five-Pointed Collar (48)
25. Foolscap with Seven-Pointed Collar (40)
26. Grapes (12)
27. Hare (3)
28. Horse and Rider (2)
29. IHP (2)
30. IHS (20)
31. King's Head (1)
32. Lion (2)
33. Man (2)
34. Paschal Lamb (11)
35. Phoenix (3)
36. Posthorn (5)
37. Pot (1)
38. Pro Patria (4)
39. Serpent (2)
40. Seven Provinces (8)
41. Star (1)
42. Strasbourg Bend (23)
43. Strasbourg Lily (91)
44. Wheel (1)

Appendix B: Sample Decision Branch Vetting Sheet

Reviewer Name: Isabella Dobson **Date:** 6/25/2020 **Watermark Type:** Basilisk **No. of Variants:** 4 **No. of Subs:** 10

WIRE
WATERMARK
IDENTIFICATION IN
REMBRANDT'S
ETCHINGS

Question number: 3
Question text: Is the tail smooth?

1a) On a scale of 1 to 5 (with 5 meaning "question makes perfect sense" and 1 meaning "don't understand"), is this question clear and functional? **Rating: 3**

1b) Again, 1 to 5, is the described feature clearly visible?
Rating: 4

2) If this question did not receive a rating of 5, is the question salvageable and if so, what are your rewording suggestions? **It is a bit ambiguous as to what constitutes a "smooth" tail. To make the question more directed and specific, it should be asked like this: "Are the lines that form the basilisk's tail smooth as opposed to bumpy?"**

3) On a scale of 1 to 5 (with 5 meaning "annotation makes perfect sense" and 1 meaning "don't understand"), is this annotation clear and functional? **Rating: 4**

4) If this annotation did not receive a rating of 5, what are some suggestions for reworking that you would add? **This annotation would benefit from including another image that shows what a bumpy tail looks like so that it can clearly be differentiated from a smooth one.**

5) Do you see a clear feature that was not used in this question? **No, the feature is clear enough.**

Current Annotated Image(s):

Suggested Annotated Image Edit:

Herbert F. Johnson Museum of Art, Cornell University

wing tips pointing upwards

wing tips pointing downwards

Basel crosier
or
Bishop's crosier
or
Fleur de lis
(see other image)

beak-side foot

letters and cross

Single-headed Eagle

Basel crosier

Bishop's crosier

Fleur-de-lis

Components of Single-headed Eagle
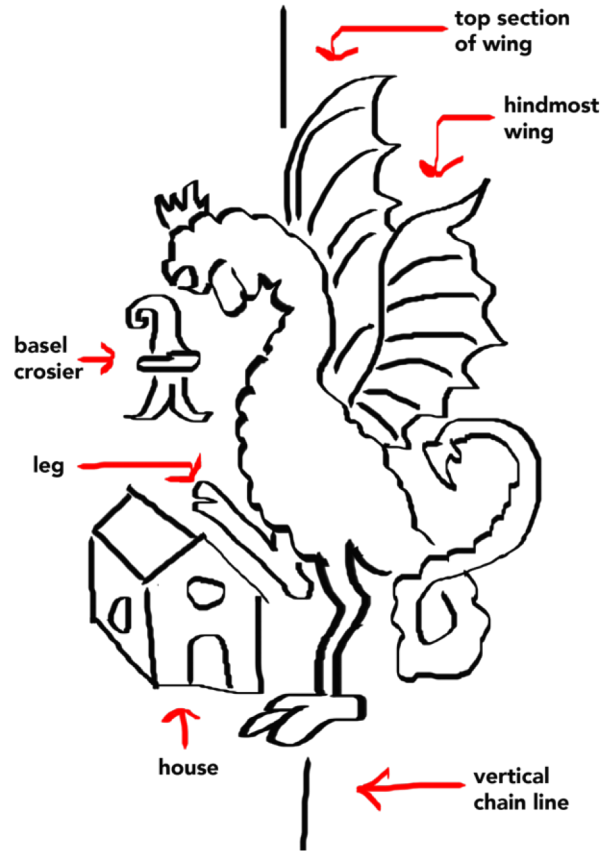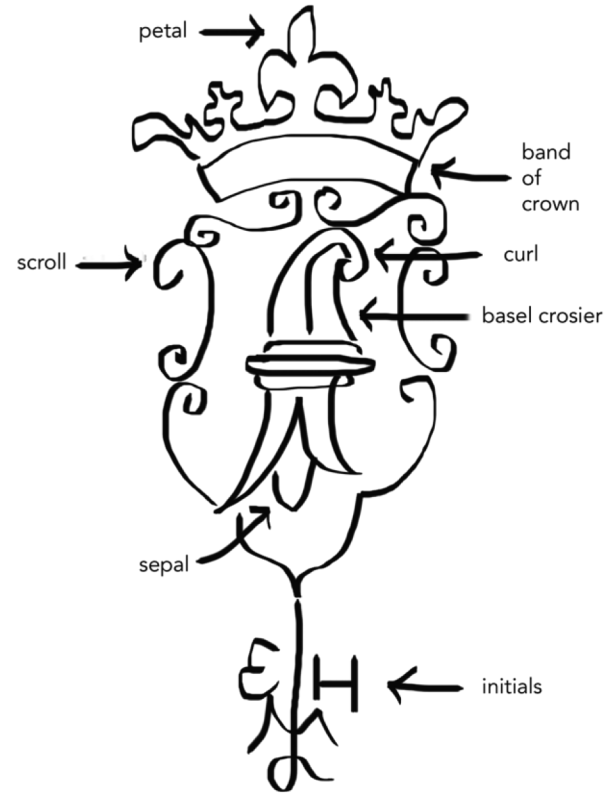
top section
of wing

hindmost
wing

basel
crosier

leg

house

vertical
chain line

Basilisk

petal

band
of
crown

scroll

curl

basel crosier

sepal

initials

Basel Crosier
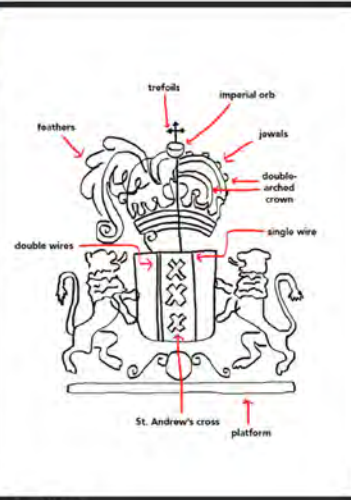
Use of hyperlinked glossary sketch in the 'Arms of Amsterdam' branch

Appendix D: Installation shots from WIRE Project decision tree visitor interactive in Laboratory Rembrandt exhibition, Rembrandt House Museum, Amsterdam, Fall 2019

Installation view of WIRE decision tree interactive in *Laboratory Rembrandt*: *Rembrandt's Technique Unraveled*
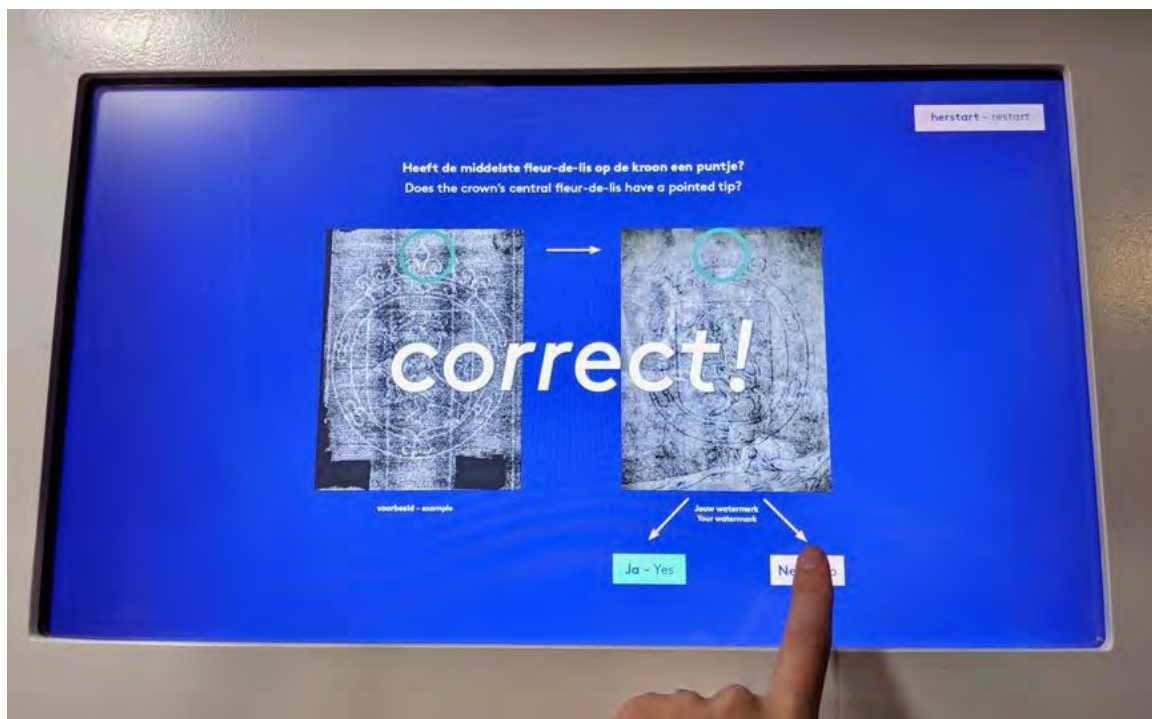
Details of interactive WIRE decision tree interface at *Laboratory Rembrandt*: *Rembrandt's Technique Unraveled*

Exhibition colophon and acknowledgements for *Laboratory Rembrandt*: *Rembrandt's Technique Unraveled*

Appendix E: Speaking Engagements and Audiences for WIRE project staff and students

Exhibitions:
- *Lines of Inquiry: Learning from Rembrandt's Etchings*, Cornell University, Herbert F. Johnson Museum of Art, September 23-December 17, 2017 [**28,812 attendees**]
- *Lines of Inquiry: Learning from Rembrandt's Etchings*, Oberlin College, Allen Memorial Art Museum, February 6-May 13 2018 [**11,930 attendees**]
- *Laboratory Rembrandt: Rembrandt's Technique Unravelled*, Rembrandt House Museum, Amsterdam, September 21, 2019-February 16, 2020 [**103,417 attendees**]

Symposia
- Andrew C. Weislogel, C. Richard Johnson, Jr., and students, "The Watermark Identification in Rembrandt's Etchings (WIRE) Project: Student Engagement, Initial Discoveries, and Future Directions", presented at symposium "Learning and Teaching with Rembrandt: Cross-Disciplinary Approaches to the Master Etcher", Cornell University, Herbert F. Johnson Museum of Art, October 28, 2017 [**125 attendees**]
- Andrew C. Weislogel, "The WIRE Project: Crowd-Sourcing Watermark Identification toward a Broader Understanding of Rembrandt's Etchings", held in conjunction with the exhibition *Leiden 1630: Rembrandt Emerges*, Queen's University, Agnes Etherington Art Centre, November 8, 2019 [**142 attendees**]

Presentations at Workshops/Scholars Days
- Andrew C. Weislogel, "Watermarks and Rembrandt's Practice: Enhancing Access to the Answers" workshop for *Lines of Inquiry* Study Day, Oberlin College, Allen Memorial Art Museum, April 6, 2018 [**22 participants**]
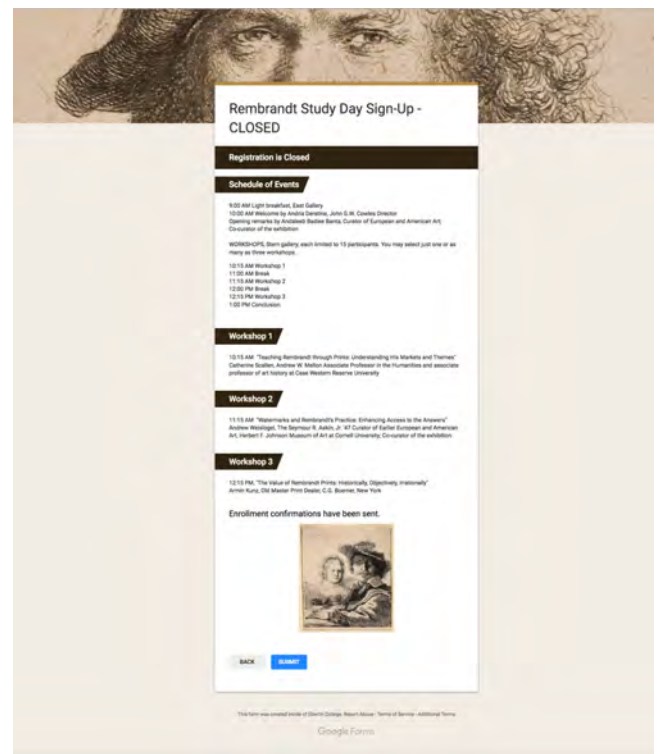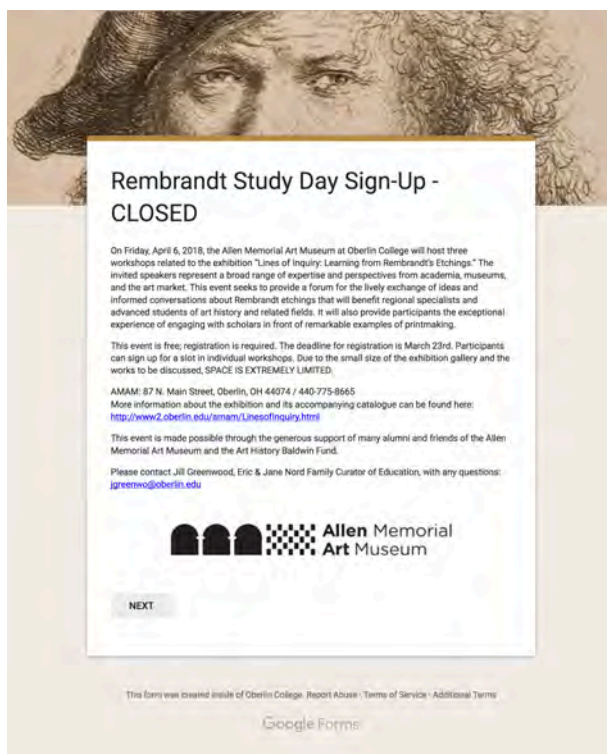
Invitation and schedule for Rembrandt Study Day, Allen Memorial Art Museum,
Oberlin College, April 6, 2018.

Dr .Weislogel leads workshop at Rembrandt Study Day, Allen Memorial Art Museum,
Oberlin College, April 6, 2018.

- WIRE Project Summer Workshop, Cornell University, Herbert F. Johnson Museum of Art, June 24-29 2018 [**8 participants, 3 staff, 2 interns, 2 guest speakers**]
- C. Richard Johnson, Jr. "Computational Characterization of Leonardo's Papers", at the conference *Decoding Leonardo's Codices*, Florence, Italy, October 12, 2019.
- C. Richard Johnson, Jr., "Rembrandt's European Papers" as Visiting Fellow in Computational Art History, National Library of the Netherlands, The Hague, October 25, 2018.

Invited Talks by project staff and students
- C. Richard Johnson, Jr., "Paper is Part of the Picture: Humans and Computers in Paper Studies", Conservation Center of the Institute of Fine Arts, New York University, April 2017.
- C. Richard Johnson, Jr., "Breaking New Ground: Computational Tools for Art Scholarship", Lunder Conservation Center, Smithsonian American Art Museum, Washington, D.C., July 20, 2017.
- C. Richard Johnson, Jr., "Matching Manufactured Patterns in Art Supports", Getty Conservation Institute Science Lecture, Los Angeles, November 27, 2017.
- C. Richard Johnson, Jr., "Matching Manufactured Patterns in Art Supports", Department of Art History, New York University, February 8, 2018.
- C. Richard Johnson, Jr., "Rembrandt's Papers: Moldmate Designation", presented at the symposium *Imaging Techniques and the Technical Study of Drawings*, Morgan Drawing Institute and Thaw Conservation Center, New York, April 25, 2018.

- C. Richard Johnson, Jr., "Rembrandt's European Papers: Computer-Assisted Classification of Watermarks and Chainline Patterns for Moldmate Identification," National Gallery of Denmark, Copenhagen, November 1, 2018.
- C. Richard Johnson, Jr., "Studying Vermeer's Canvases and Rembrandt's Papers: Two Examples of Computational Art History," for the Milstein Program in Technology and Humanity, Cornell University, November 9, 2018.
- C. Richard Johnson, Jr., "The WIRE Project at Cornell Examines the Frick Collection's Rembrandt Prints with Watermarks", Digital Art History Lab Lecture Series, followed by a panel discussion featuring Andrew Weislogel, WIRE project advisor Margaret Holben Ellis, and WIRE students, Frick Collection, New York, December 6, 2018.

Top: C. Richard Johnson, Jr., Andrew C. Weislogel, Margaret Holben Ellis, and Margaret Iacono taking part in a panel discussion following Dr. Johnson's talk at the Frick Collection, December 6, 2018.
Bottom: WIRE project students Katrina Ferreira, Nina Simpkins, Margaret Canfield, Sara Gorske and Orrin Kigner

- Andrew C. Weislogel and C. Richard Johnson, Jr., "The WIRE Project at Cornell: A Crucible for Student Research in the Emerging Field of Computational Art History", for the Cornell Association of Professors Emeriti, Cornell University, December 13, 2018.
- C. Richard Johnson, Jr., "Watermark Identification in Rembrandt's Etchings: Decision Tables, Decision Trees, and Fragments", in conservation course "The Conservation Treatment of Prints and Drawings II, Conservation Center of the Institute of Fine Arts, New York University, February 15, 2019.
- Brittany Rubin, "New Insights on Old Objects: Maximizing the Impact of Collaborative Technical Research at the Academic Art Museum. Association of Academic Museums and Galleries", presented at the conference *Learning Laboratory and Community Center: Positioning the Academic Museum for Success,* University of Minnesota, Minneapolis, June 29, 2019.
- C. Richard Johnson, Jr., "Laid Paper Inner Structural Features as Batchmate Indicators", Thaw Conservation Center, The Morgan Library, New York, July 22, 2019.
- C. Richard Johnson, Jr., "Laid Paper Inner Structural Features as Batchmate Indicators", Digital Art History Lab, The Frick Collection, New York, July 26, 2019.
- C. Richard Johnson, Jr., "Laid Paper Inner Structural Features as Batchmate Indicators", Department of Prints and Drawings, The Metropolitan Museum of Art, New York, August 27, 2019.
- Andrew C. Weislogel, "Tales from the Vault: Netherlandish and German Prints at the BMA", Baltimore Museum of Art, September 27, 2019.
- C. Richard Johnson, Jr., "Adventures in Computational Art History: Hunting for Rollmates among Vermeer's Paintings and Moldmates Among Rembrandt's Prints on Laid Paper", Philadelphia Museum of Art, November 15, 2019.
- C. Richard Johnson, Jr., "Studying the Internal Structure of Historic Papers", Getty Institute Science Lecture, Los Angeles, January 8, 2020.
- Andrew C. Weislogel and Brittany Rubin, "CHESS and the Johnson Museum: Partners Past, Present, and Future," June 10, 2020. Talk about future avenues for the study of cultural heritage using x-rays.

Student presentations:
- Metropolitan Museum of Art, presenting to WIRE advisory team (Margaret Holben Ellis, Erik Hinterding, Nadine Orenstein), October, 2016, October 2017
- Isabella Dobson, Margaret Canfield, Mariana Seibold, presenting to conservation staff, The Morgan Library and Museum, New York, April 18, 2019.

April, 2019 WIRE student visit to the Morgan Library. Left: Brittany R. Rubin (standing) leads Mariana Seibold and Isabella Dobson in the examination of a watermarked Rembrandt print. Right: Senior paper conservator Reba Snyder (standing) discusses imaging watermarks using beta radiography.

Courses About or Presenting the Project:

- ARTH 4492/4492: offered Fall 2017, Spring 2018, Fall 2018, Spring 2019 at Cornell University
- ARTH 1110: offered Fall 2017, Fall 2018 at Cornell University
- ARTH 4451: offered Spring 2020 at Cornell University

WIRE project Museum site visits:

- Smith College Museum of Art, September 2018
- Mead Art Museum, Amherst College, September 2018
- Yale University Art Gallery, January 2019
- Spencer Museum, University of Kansas, June 2019
- Hood Museum, Dartmouth College, June 2019
- Rijksmuseum, Amsterdam, March 2020
- Rembrandthuis, Amsterdam, March 2020
- Isabella Dobson, Margaret Canfield, Mariana Seibold, Morgan Library & Museum, New York, presenting to conservation staff, April 18, 2019.

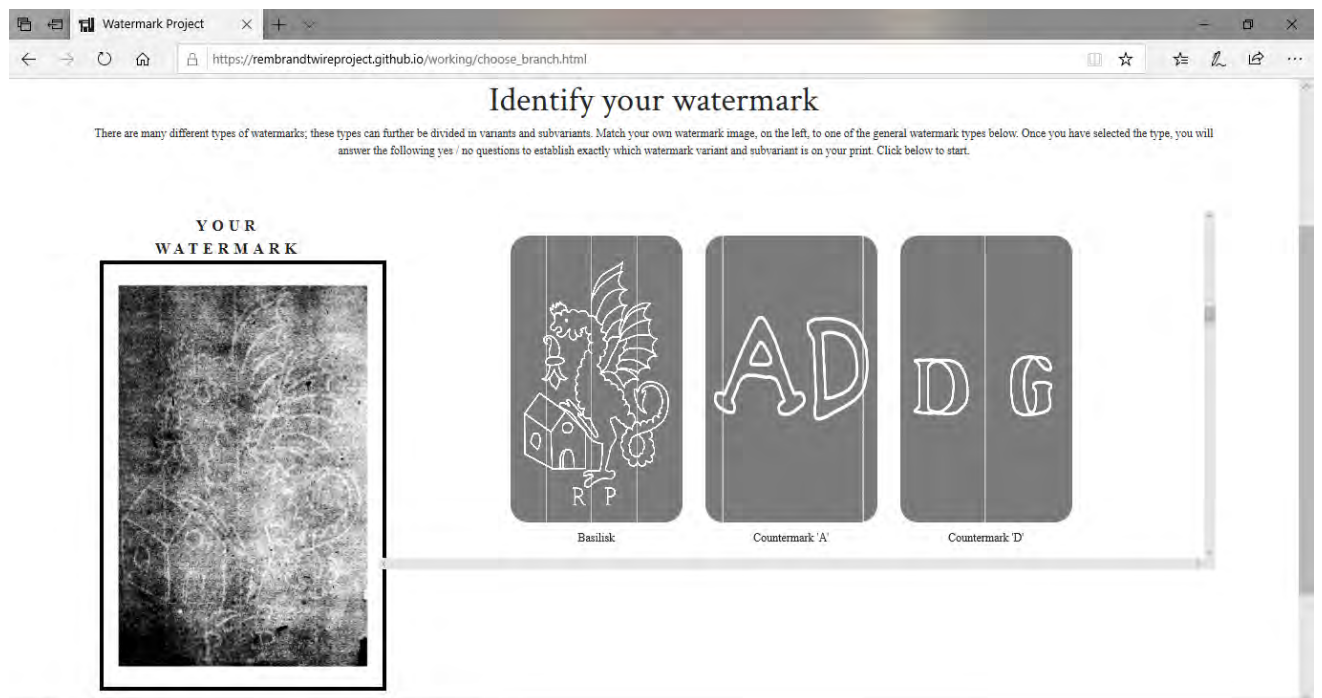# Basilisk decision tree as seen on the WIRE website

1. WIRE website home page
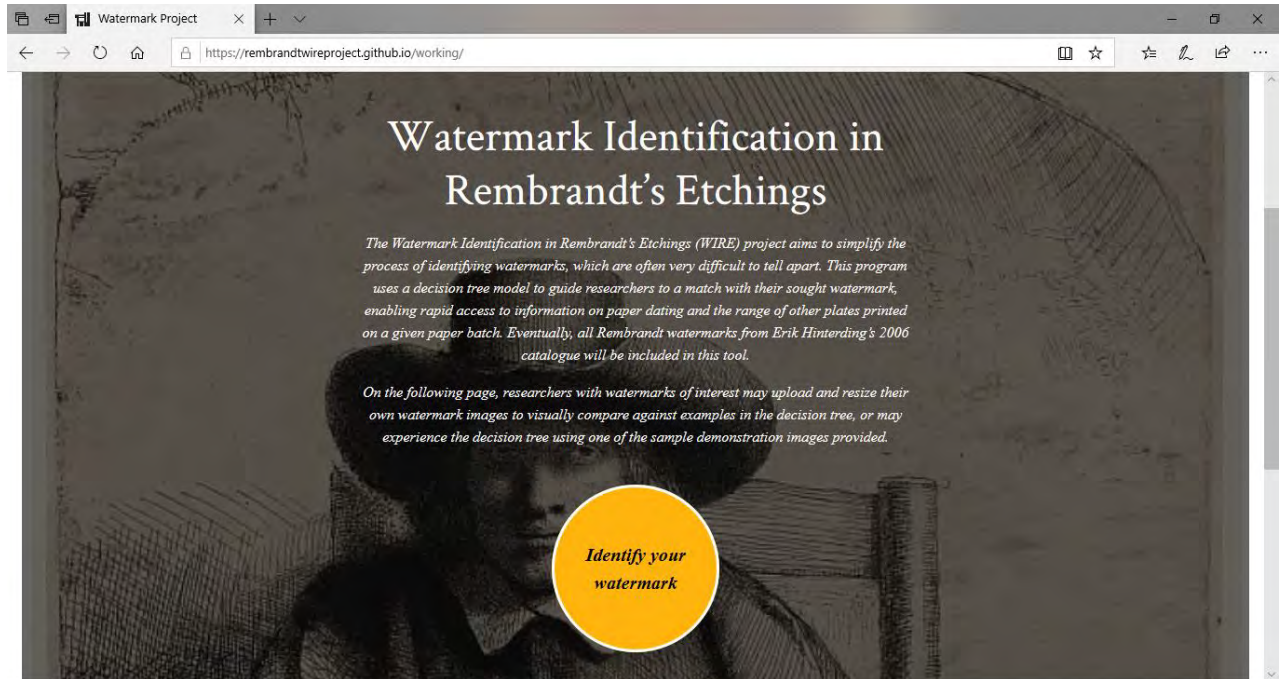
2. Selecting or uploading the watermark image
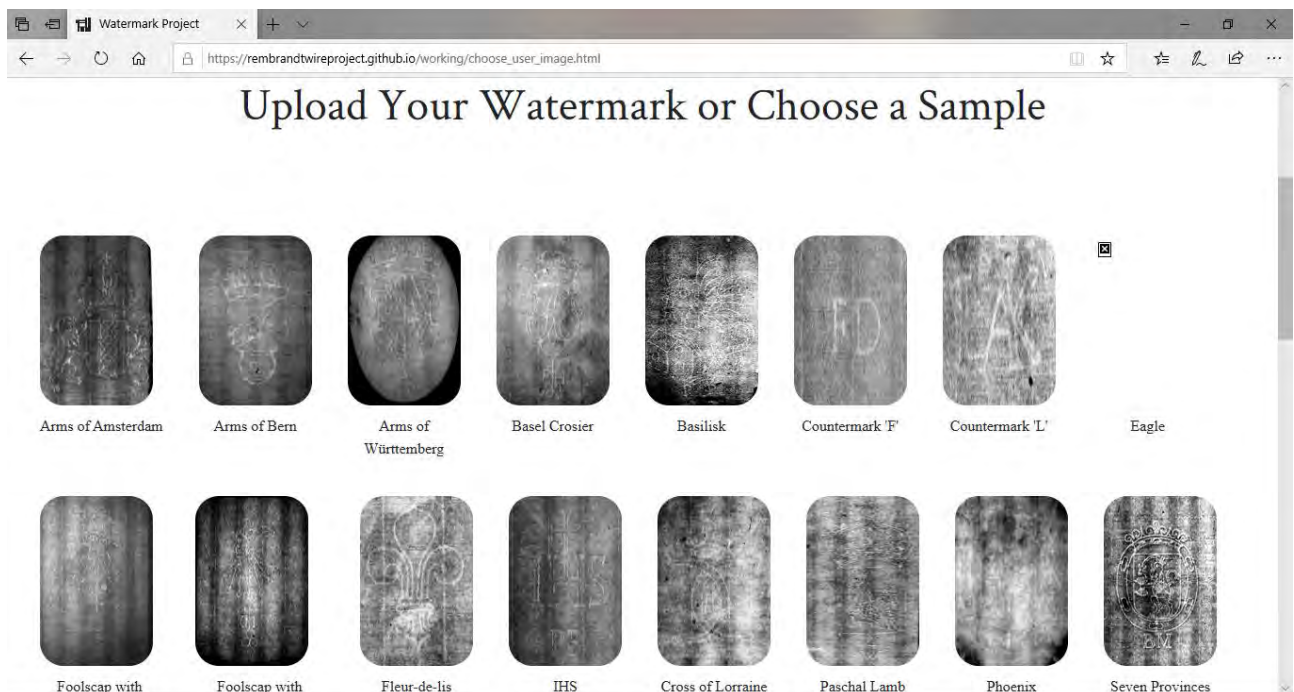
3. Cropping and adjusting the selected watermark image
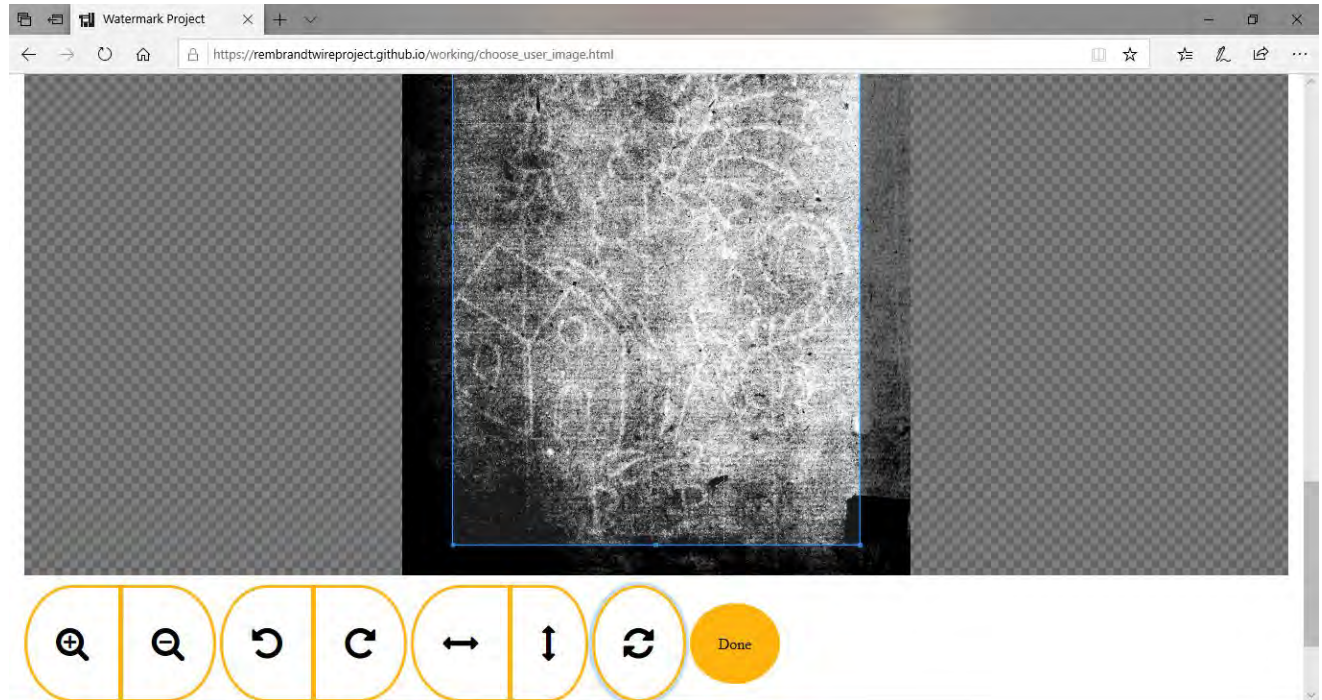
4. Choosing the watermark type that resembles the selected image

5. First question of the Basilisk decision tree

6. Second question of the Basilisk decision tree

7. Third question of the Basilisk decision tree

8. Fourth question of the Basilisk decision tree

9. Arriving at the correct watermark identification

WIRE Decision Tree Instruction Manual

Isabella Dobson

June 2020

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I. Introduction

The chief product of the NEH WIRE Digital Humanities Advancement Grant Level II project FAID HAA-256123-17 is an online decision tree for the identification of watermarks on Rembrandt's etching papers.

A decision tree organizes a series of yes or no questions into the form of a branching diagram. Each question answered guides the user to a new question until they reach an end node, or terminal point, with a watermark that exactly matches and therefore correctly identifies their sought watermark according to Rembrandt watermark scholarship as presented in Erik Hinterding, *Rembrandt as an Etcher: The Practice of Production and Distribution*, Ouderkerk aan den IJssel (Sound and Vision Publishers), 2006.[1] The purpose of this manual is to illuminate and delineate the thought process behind the construction of decision trees for watermark identification, as well as instruct the reader on how to develop and code these decision trees onto the WIRE website. Accordingly, constructing a decision tree branch and coding a decision tree branch are the two main sections of this manual, but each of these is subdivided into smaller sections.

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[1] All watermark images in this manual appear courtesy of Sound & Vision Publishers, BV.

II. Constructing a Decision Tree Branch

A. Determining Distinguishing Watermark Features

1. To construct a decision tree for a particular watermark type, start with a folder of radiographic images of all of the members of that type (Basilisk, Paschal Lamb, Seven Provinces, etc.) Spend some time looking at all the watermarks within the type and jot down a list of the features that could be used to distinguish them from one another.

   a. This list does not have to be exhaustive and will be different for every branch, but it can include countable objects such as roundels, petals, or jewels, symbols such as letters or numbers, or remarks on chain line positioning and intersections.

2. Next, try to match a distinguishing feature from this broad list to the variant categories.

   a. In Hinterding's classification system, the first capitalized letter of a watermark's name denotes its variant level. Thus, all the watermarks whose classification begins with an A belong to the same variant. Variants share a common and differentiating feature.

   b. Separate watermarks into these variant groups by finding the feature that makes each variant unique. An example list, with accompanying images, for the Basilisk branch is shown below.

      i. Bumpy tail: Variant A
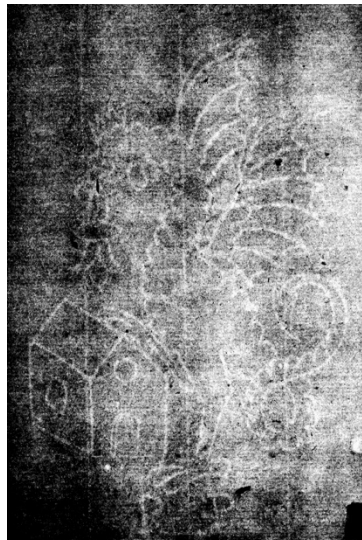
ii. Smooth tail: Variant B
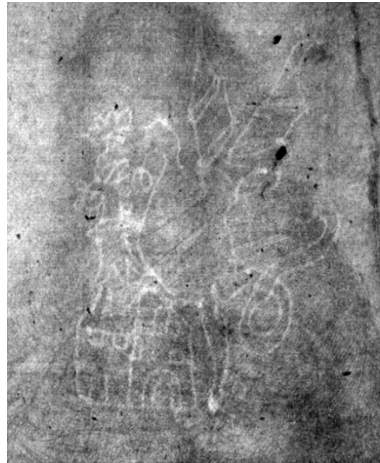
iii. Shield next to basilisk: Variant C
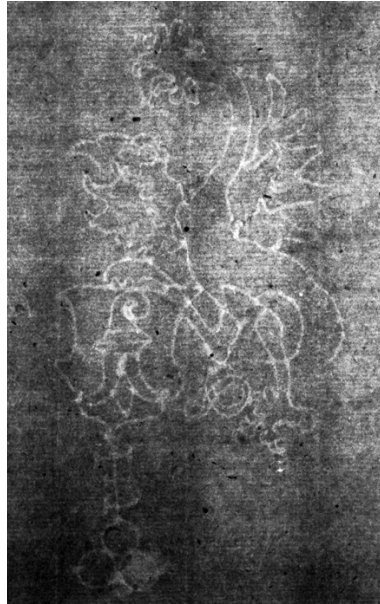
iv. Horizontal chain lines: Variant E
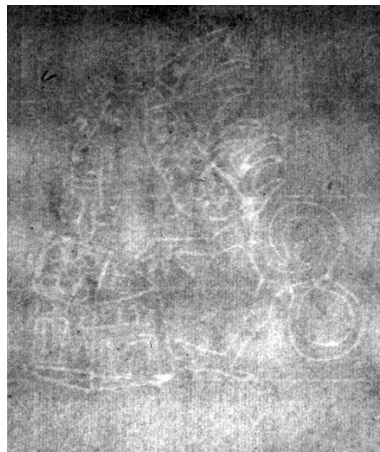
3. Further separate variant groups by distinguishing among subvariants.
   a. In Hinterding's classification system, the second lowercase letter of a watermark's name denotes its subvariant level.
   b. Separate variants into subvariants by finding a feature that distinguishes it among the other subvariants. For the Basilisk branch, the only variant which is subdivided into subvariants is variant B, so its example subdivision is shown below.
      i. One of the Basilisk's legs comes between its belly and the house-Subvariant B.b.
      ii. The tip of the tail crosses the chain line-Subvariant B.a.
      iii. The tip of the hindmost wing touches the chain line-Subvariant B.d.
      iv. The tip of the hindmost wing does not touch the chain line-Subvariant B.c.

B. Crafting Questions from Features

1. Now these distinguishing features must be converted into questions with a "yes" or "no" answer and translated into the format of the decision tree (Fig. 1).
   a. To begin, select a distinguishing feature from the variant list, turn it into a "yes" or "no" question, and write it down at the top of a piece of scratch paper. This is the first question of the branch and should divide one variant from all the others (It could also divide two variants, three variants, etc. from the others). For example, the first question of the basilisk branch isolates the E variant from all the others.
   b. Next, jot down all the remaining subvariants for both the "yes" and "no" sides above their respective arrows. These notations will not be present in the final digital version of the branch diagram, but it is a helpful tool for visualizing which subvariants still remain as one constructs the tree.
   c. Move down the tree continuing to separate variants from each other using questions formed from the distinguishing features list.
   d. When all the variants have been divided out, separate the subvariants from each other with questions about their distinct features.
   e. Finally, if desired, separate twinmarks from one another. However, this is more difficult to do since twinmarks were

deliberately made to resemble each other as closely as possible and they have the same date anyway since the two molds were made to be used in tandem.
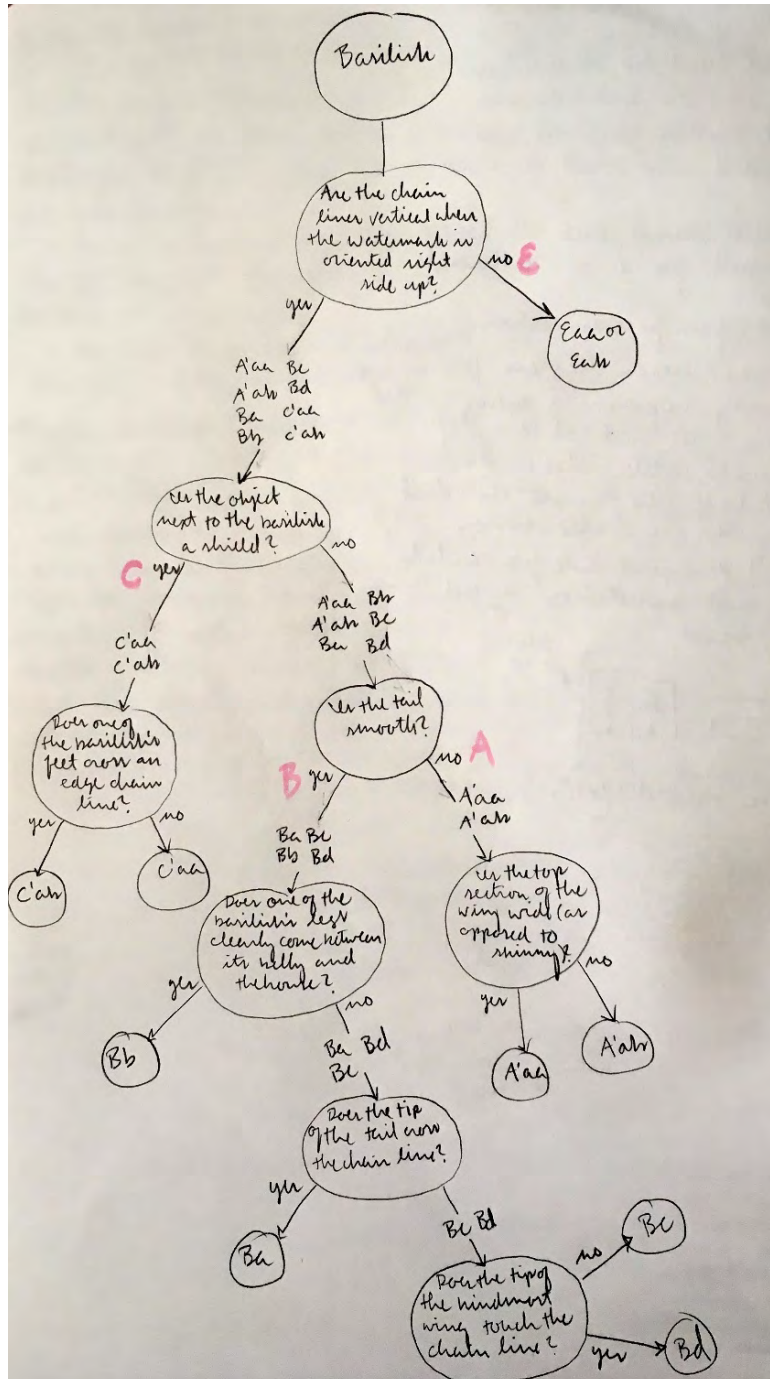
Figure 1-Converting features to questions with a hand-drawn decision tree

2. After the decision tree has a path to every possible variant, the questions and their annotated images should be assembled together into a PowerPoint slide show (See fig. 2 for an example slide). The presentation of this PowerPoint to the rest of the WIRE team served as a platform for evaluating and workshopping the questions and their accompanying images to ensure clarity and accuracy.
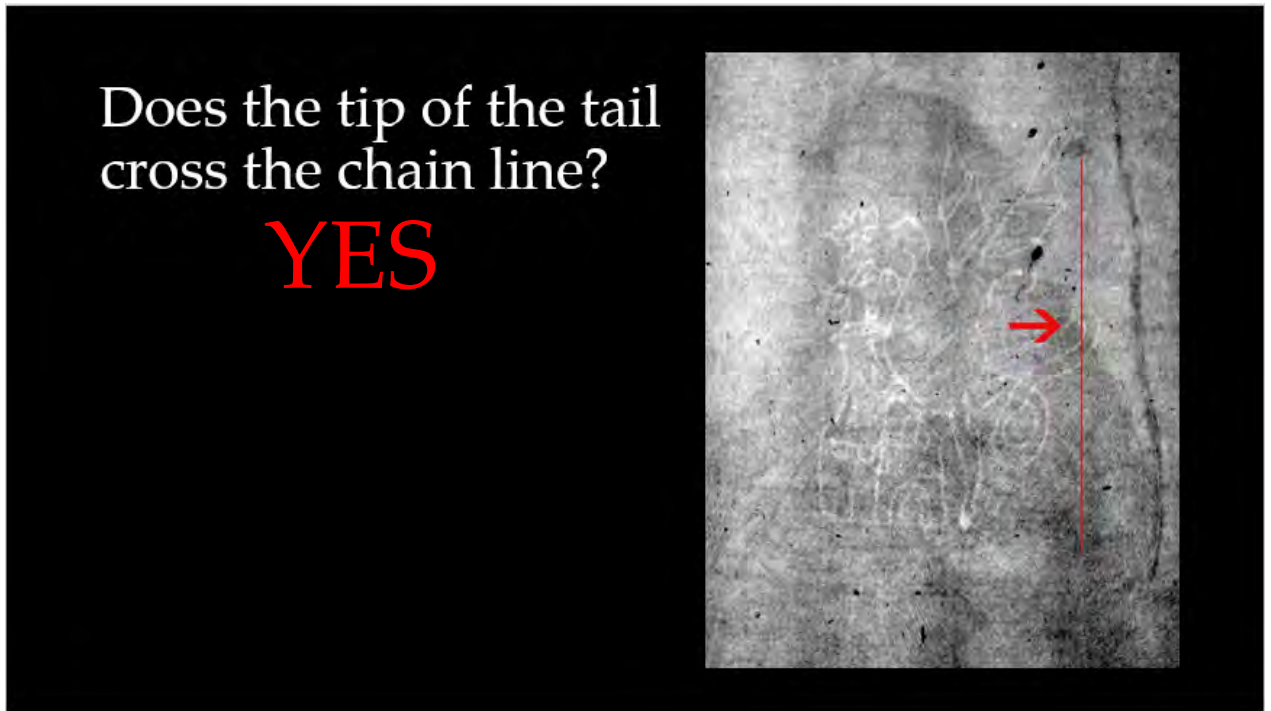
Figure 2-Example slide from a question development PowerPoint

C. Constructing a Decision Tree Branch Diagram

1. A branch diagram presents the formalized version of a completed branch so that users can see the whole picture of how a watermark's variants interrelate, prior to its coding into the online decision tree. WIRE project participants create these diagrams using Google's free draw.io program.
2. Open draw.io by typing https://app.diagrams.net/ into the address box.
3. Select "Create new diagram" when automatically prompted.
4. First, create a bubble to serve as the title for the branch and position it at the top center of the page. The bubble should have a black background with the name of the branch written in white Avenir font.
5. Next, create a bubble with a light orange background and dark orange outline to contain the branch's first question. Type the question in black Avenir font.

6. Place the first question bubble underneath the branch title bubble and connect them with an arrow the same dark orange color as the bubble outline.
7. Watermark end node bubbles follow the same design specifications as the question bubbles and should be connected to them using the same dark orange arrows from the previous step.
8. Above the arrows on the left sides of bubbles, place a text box containing the word "YES" in black Avenir font. Similarly, place a text box containing the word "NO" in black Avenir font above the arrows on the right sides of bubbles.
9. Variant bubbles should be colored dark orange and contain the capital letter which corresponds to the variant it is leading to. Place these on top of the arrows whenever the branch splits off into a different variant.
10. Continue to build the tree using the above specifications until all the questions and watermarks have been inputted. See an example of a small branch with these specifications below step 10.
11. Save the diagram by clicking on "Export as"-> "PDF" from the "File" menu. See figure 3 for an image that includes all of the above features.

Figure 3-Example of a correctly formatted decision tree diagram

D. Annotating Images to Point Out Features

1. Annotated images appear alongside each question to assist the viewer in correctly answering the question for their watermark. The first option for making an annotated image is making a single annotation (Fig. 4).

a. First, select a single image of a watermark that clearly shows the distinguishing feature the question is inquiring about and open it in photo editing software such as Adobe Photoshop or Microsoft Paint.
b. Next, add red markings to the image to highlight the distinguishing feature. These markings can include any combination of boxes, circles, solid lines, dashed lines, and arrows. For instance, the single annotation below uses a solid line to highlight where the chainline is. Additionally, it uses an arrow to point out where the wing touches the highlighted chainline.
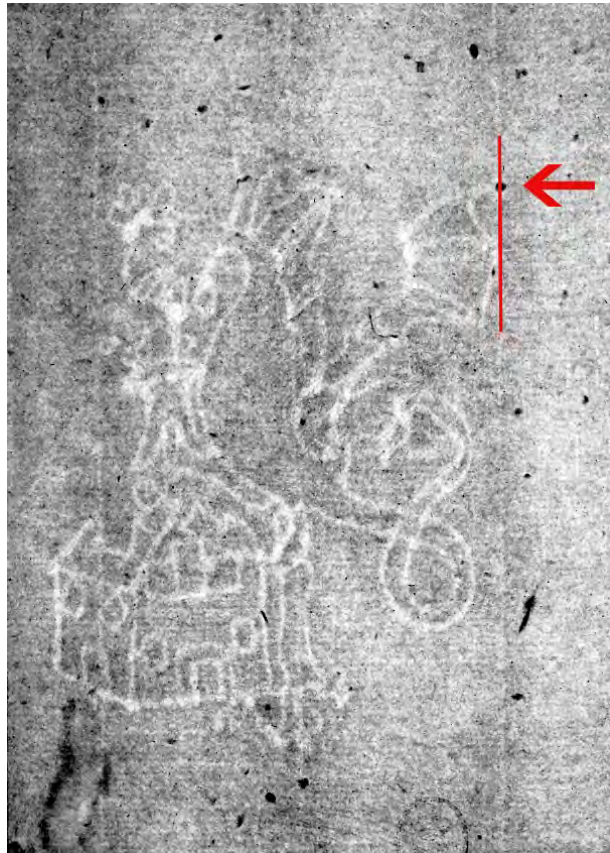
Figure 4– Single image annotation for the question "Does the tip of the hindmost wing touch the chain line?"

2. The second option for making an annotated image is a double annotation (Fig. 5).

        a. First, select two images of a different watermark; one needs to be an example of a watermark that answers "yes" to the question and the other must be an example of a "no" answer.

        b. Open them in photo editing software such as Adobe Photoshop or Microsoft Paint and combine them into a single file with the "yes" image on the left and the "no" image on the right.

        c. Next, add red markings to both watermark images to highlight the distinguishing feature. For instance, the double annotation below uses both a circle to surround the area of focus (the wing) and an arrow to emphasize the particular quality of the wing (its width) that the question is asking about.
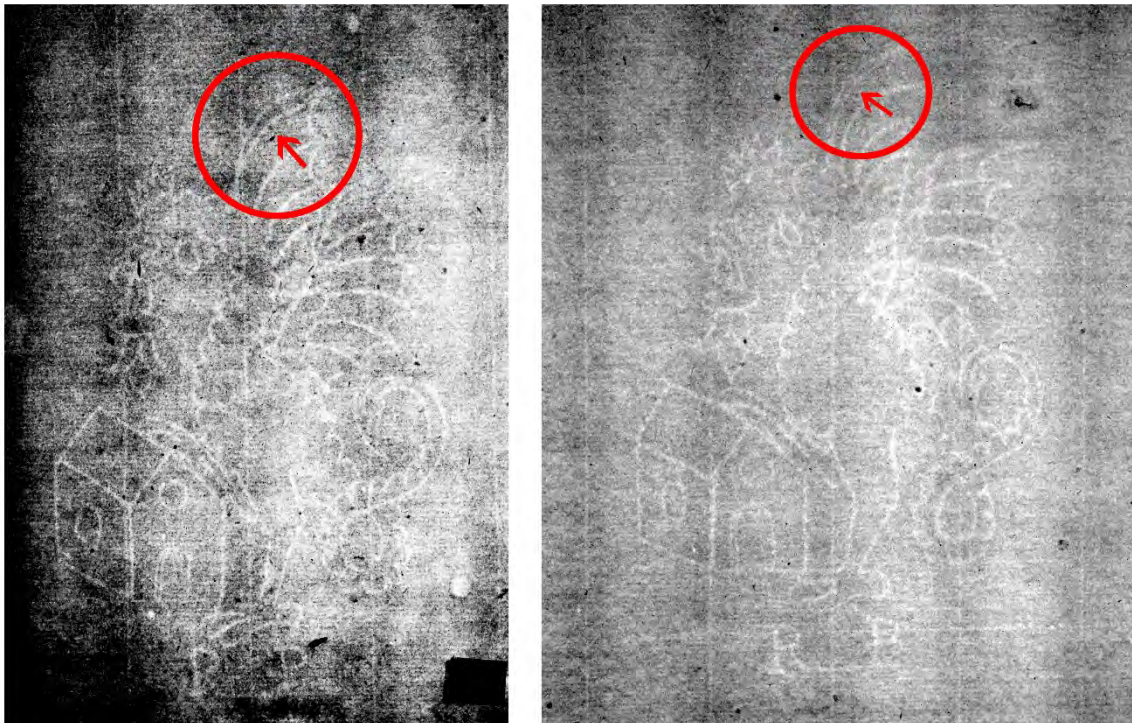
Figure 5– Double image annotation for the question "Is the top section of the wing wide (as opposed to skinny)?"

E. Making a Decision Table [optional]

1. The decision table is a tool that the WIRE project has employed to minimize the number of questions asked before arriving at the correct watermark, to lessen the time required to obtain a correct answer, and to

explore the construction of decision trees as a math problem to further optimize the decision tree approach.

    a. The table should be set up with a column for each of the questions in the branch's decision tree and a row for each of the watermark end nodes. See the example table with its corresponding questions set up below for the Arms of Württemberg branch.

        1. Are there two letters below the crest?
        2. Is the straight stroke of the letter 'B' parallel to the chain lines?
        3. In the quadrant of the crest with diamonds, do four equally sized diamonds form a larger full diamond?
        4. Do the letters 'LB' appear below the crest?
        5. Does the side of the crest with the fish and the diamonds meet the chain line at one point?

	Q1	Q2	Q3	Q4	Q5
A.a.a.					
A.a.b.					
A.a.b.					
B.a.					
B'.a.a.					
B'.a.b.					

    b. Then answer each question for every watermark, filling in the corresponding box with "yes" or "no". Ideally, all the questions should be answerable for every watermark, but if the watermark does not have the feature the question asks about, then the branch must be reworked for the purpose of this exercise. The table has been filled in below for the Arms of Württemberg branch.

	Q1	Q2	Q3	Q4	Q5
A.a.a.	No	Yes	Yes	No	No
A.a.b.	No	Yes	No	No	No
A.a.c.	No	No	Yes	No	No
B.a.	Yes	Yes	No	No	No
B'.a.a.	Yes	Yes	No	Yes	Yes
B'.a.b.	Yes	No	No	Yes	No

c. Once the decision table has been completed, a decision tree can be extracted from it. To find the first question of the decision tree and minimize the average number of questions answered before arriving at the correct watermark, choose a question column that has about half "yes" and half "no" answers. In the case of the above decision table, question column 1 fits this description since it has three "yes" answers and three "no" answers.

d. Next, look at the remaining question columns for one half of the subvariants and use them to isolate these subvariants in as few questions as possible. For the "yes" side of Arms of Württemberg (highlighted in pink in the table below), B.a.a can be separated from B'.a.a. and B'.a.b. with question 4 and B'.a.a. can be separated from B'.a.b. with question 5. Similarly, on the "no" side (highlighted in blue in the table below), A.a.c. can be separated from A.a.a. and A.a.b. with question 2 and A.a.a. can be separated from A.a.b. with question 3.

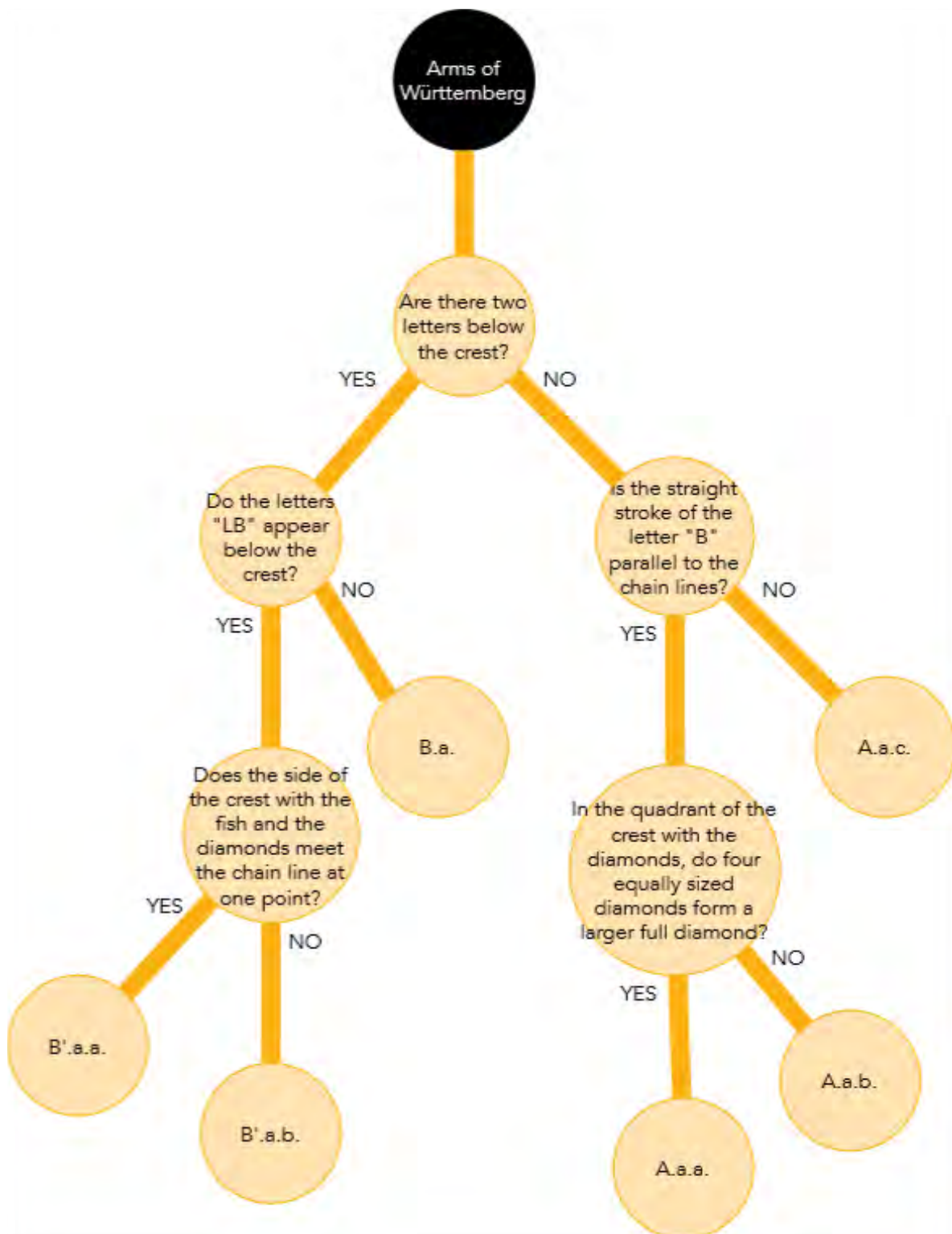|	Q1	Q2	Q3	Q4	Q5
A.a.a.	No	Yes	Yes	No	No
A.a.b.	No	Yes	No	No	No
A.a.c.	No	No	Yes	No	No
B.a.	Yes	Yes	No	No	No
B'.a.a.	Yes	Yes	No	Yes	Yes
B'.a.b.	Yes	No	No	Yes	No

Figure 6 below is the resulting decision tree.

Figure 6-Arms of Württemberg decision tree resulting from decision table

e. Now that a decision tree has been extracted, write the question number path that leads to each subvariant and note how many questions it takes to isolate it.

Subvariant	Question path	# of questions
A.a.a.	1-2-3	3
A.a.b.	1-2-3	3
A.a.c.	1-2	2
B.a.	1-4	2
B'.a.a.	1-4-5	3
B'.a.b.	1-4-5	3

f. Calculate the average number of questions the user must be asked to isolate a subvariant by adding up the number of questions column and dividing this sum by the number of subvariants. Thus, the average number of questions asked to isolate a subvariant in this configuration of the Arms of Wurttemberg branch is $(3+3+2+2+3+3)/6=$**2.67**.

g. For this particular example branch, this is the lowest possible average. The above process can be repeated for multiple branch configurations in order to find the configuration with the most efficient path on average to a subvariant.
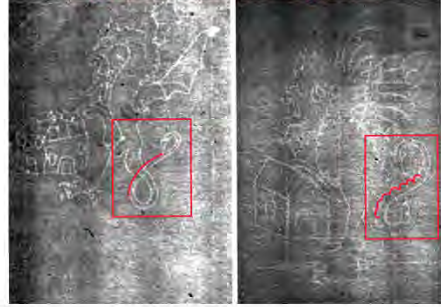
F. Vetting a Completed Branch

1. The final step before coding is to make sure that the user can easily navigate the decision tree, ultimately arriving at the correct watermark. This vetting process was carried out first by students and staff involved in the WIRE project and then by HFJ staff members and members of partner institutions not directly involved in the project. A questionnaire was developed to standardize the vetting of branches (Fig. 7).

2. The vetter must evaluate the following for each question of a decision tree:
   a. Clarity and functionality of question text: Is the question too verbose? Does the question make sense in general? Does the wording merely need to be tweaked a little, or should the question be scrapped entirely?
   b. Visibility of the described feature: Does the question ask about a feature that is unobscured and easily discernible? Is there a

different distinguishing feature than the one used in the question that is not so ambiguous?

    c. Clarity and functionality of annotated image: Do the red markings effectively draw the viewer's eye to the question's target without obscuring it? Should a different marking be used (e.g. an arrow instead of a circle)? If it is a single annotation, would a double annotation increase clarity?

3. After any concerns brought up by these questions have been discussed and satisfactorily addressed and modified by the participating parties, then the branch is ready to be coded into the WIRE website.

Reviewer Name: Isabella Dobson   **Date:** 6/25/2020   **Watermark Type:** Basilisk   No. of Variants: 4   No. of Subs: 10

WIRE WATERMARK IDENTIFICATION IN REMBRANDT'S ETCHINGS

Question number: 3
Question text: Is the tail smooth?

1a) On a scale of 1 to 5 (with 5 meaning "question makes perfect sense" and 1 meaning "don't understand"), is this question clear and functional? **Rating: 3**
1b) Again, 1 to 5, is the described feature clearly visible?
                       Rating: 4
2) If this question did not receive a rating of 5, is the question salvageable and if so, what are your rewording suggestions? **It is a bit ambiguous as to what constitutes a "smooth" tail. To make the question more directed and specific, it should be asked like this: "Are the lines that form the basilisk's tail smooth as opposed to bumpy?"**

3) On a scale of 1 to 5 (with 5 meaning "annotation makes perfect sense" and 1 meaning "don't understand"), is this annotation clear and functional? **Rating: 4**

4) If this annotation did not receive a rating of 5, what are some suggestions for reworking that you would add? **This annotation would benefit from including another image that shows what a bumpy tail looks like so that it can clearly be differentiated from a smooth one.**

5) Do you see a clear feature that was not used in this question? **No, the feature is clear enough.**

Current Annotated Image(s):

Suggested Annotated Image Edit:

Herbert F. Johnson Museum of Art, Cornell University

Figure 7-Sample vetting worksheet for Basilisk type, question 3

III. Coding a Decision Tree Branch

A. How to Download and Install Coding Software on a PC[2]

1. Installing Github
   a. Open any internet browser and type https://desktop.github.com into the address box.
   b. Click "Download for Windows" and save Github to your desktop.
   c. From the desktop, double click on the Github icon to open the program and click "run" to install it.
   d. Github should start up once it has been installed.

2. Installing Atom
   a. Go back to your internet browser and type "https://atom.io" into the address box.
   b. Click "Download for Windows" and save Atom to your desktop.
   c. From the desktop, double click on the Atom icon to open the program and click "run" to install it.
   d. Atom should start up once it has been installed.

3. Cloning the WIRE repository onto your personal machine
   a. Open Github and click on "clone a repository" and enter the repository name, "rembrandtwireproject/working", into the box. Then click "Done".
   b. The user now has a copy of the WIRE website on their personal machine to edit and make changes to.

4. Setting up Github to work with Atom
   a. With Github still open, click on "File" and choose "Options" from the dropdown menu. Then click on "Advanced", make sure the external editor selected is Atom, and click "Save".
   b. Next, click on "Repository" and choose "Open in Atom" from the dropdown menu which will open the user's copy of the website in Atom. This is how the user will access Atom every time they want to make changes to the code. The user is now ready to edit.

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[2] Instructions for how to download the software onto a Mac machine can be found at this url: https://vod.video.cornell.edu/media/Getting+Started+with+WIRE+on+Mac/0_r5u2f5i2 and a video demo version of the above instructions for a PC can be found at this url: https://vod.video.cornell.edu/media/Getting+Started+with+WIRE+on+Windows/0_bdn7i70h

B. Starting a New Branch[3]
1. Creating the branch's main folder
   a. Open Github, click on "Repository", and select "Show in Finder" on a Mac or "Show in Explorer" on a PC from the dropdown menu.
   b. Open the "_pages" folder and create a new folder within it named after the watermark branch you're working on. Taking the Basilisk branch as an example, its branch name should be "basilisk". This name is called a slug and it cannot be capitalized or include any spaces.
2. Adding a branch diagram to the main folder
   a. Drag and drop or copy and paste a PDF file of the completed branch diagram into the main folder just created.
3. Creating an images folder
   a. Open the main folder and create a new folder within it which must be titled "images".
   b. Drag and drop or copy and paste an image into the "images" folder that is representative of the whole branch to serve as the icon from which the website user will choose their watermark type. This image file must be called "archetype."
4. Changing the "branches.yml" file
   a. From Github, click on the "Repository" tab and select "Open in Atom" from the dropdown menu.
   b. In the "Project" sidebar, select the file "branches.yml" from the folder "_data".
   c. Within the "branches.yml" file, type the branch's slug, in this case "basilisk", and place a colon after it.
   d. The next line down indicates the name of the branch that will appear for the user on the website. For our example branch, this line should read "name: Basilisk".
   e. The following line should indicate the image which will be used as the representative image for the branch. It should read "image: archetype".
   f. As with any changes you make in Atom, make sure you hit "Save" from the "File" menu after making these modifications.
5. Creating an index file for the branch

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[3] Video instructions for how to start a new branch can be found at this url:
https://vod.video.cornell.edu/media/Creating+a+WIRE+Branch/0_eetd31fp

a. Still in Atom, copy and paste an "index.html" file from a previous branch into the new branch folder. This will be the starting point for the branch and must always be called "index".
b. The first line of the "index" file should already be populated and should always read "layout: index".
c. The next line down should read "start:" followed by the slug name for the first question of the branch. For Basilisk, the first question's slug is "chainline_vertical", so this line should read "start: chainline_vertical".

6. Creating a diagram file for the branch
a. Still in Atom, copy and paste a "diagram.html" file from a previous branch into the new branch folder. No changes need to be made to this file since it must be the same for every branch.

7. Committing changes to the website
a. Now go back into Github where you should see all the saved changes appear in a list on the left-hand sidebar.
b. In the "Summary" field box, type a quick description of the listed changes.
c. Hit the blue "Commit to master" button and then finally "Push origin" to write the changes to the website.

C. Creating a New Question[4]

1. Creating the question file text
a. After opening Atom from Github by selecting "Open in Atom" from the "Repository" menu, copy and paste a question file from a previous branch into the new branch folder.
b. Rename this question file so that it matches the slug of the question you are creating a question file for. For example, to create a question file for the first question of the Basilisk branch, the file's name would be "chainline_vertical".
c. The first line of a question file should always read "layout: question".
d. The next line should read "question:", followed by the human readable version of the question that the user will see on the website. It looks like this for the first question of the Basilisk branch:

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[4] Video instructions for how to create a new question can be found at this url:
https://vod.video.cornell.edu/media/Creating+a+WIRE+Question/1_ljev1tnt

"question: Are the chain lines vertical when the basilisk is right side up?"

    e. The succeeding line should read "parent:", followed by the slug of the question which preceded this one. Since our example is the first question of the Basilisk branch, it should read "parent: index".

    f. The next line should read "if-yes:", followed by the slug of the question that will appear if the user answers "yes" to this question. It looks like this for the Basilisk branch: "if-yes: object_shield".

    g. The next line should read "if-no:", followed by the slug of the question that will appear if the user answers "no" to this question. Since a "no" answer for this particular question of the Basilisk branch leads to a watermark as opposed to another question, it looks like this: "if-no: Eaa".

    h. Save these changes in Atom and then commit them to the website via Github.

2. Making an annotated image appear with the question file text

    a. From Github, select "Show in explorer" from the dropdown menu under "Repository".

    b. Copy and paste or drag and drop the annotated image that corresponds to the question file you just created (their file names need to be exactly the same) into the branch's "images" folder created in step II.B.*3*.

D. Creating a New End Node[5]

1. Creating the end node file text

    a. After opening Atom from Github by selecting "Open in Atom" from the "Repository" menu, copy and paste an end node file from a previous branch into the new branch folder.

    b. Rename this end node file so that it matches the slug of the subvariant you are creating an end node file for. For example, to create an end node file for Basilisk twinmarks E.a.a. and E.a.b., the file's name would be "Eaa".

    c. The first line of an end node file should always read "layout: watermark".

    d. The next line should read "name:", followed by the human readable version of the subvariant that the user will see on the

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[5] Video instructions for how to create a new end node can be found at this url: https://vod.video.cornell.edu/media/Creating+a+WIRE+Watermark/1_q40jykvd

website. It looks like this for Basilisk subvariants E.a.a and E.a.b.: "name: Basilisk E.a.a. (or twinmark E.a.b.)".

     e. The succeeding line should read "parent:", followed by the slug of the question which preceded this end node. Since our example is preceded by the question whose slug is "chainline_vertical", it should read "parent: chainline_vertical".

     f. Save these changes in Atom and then commit them to the website via Github.

2. Making an image appear with the end node file text

     a. From Github, select "Show in explorer" from the dropdown menu under "Repository".

     b. Copy and paste or drag and drop the image of the watermark that corresponds to the end node file you just created (their file names need to be exactly the same) into the branch's "images" folder created in step II.B.3.